MIGRATION ISSUES IN THE
DEMOCRATIC REPUBLIC OF CONGO

THESIS

Michael J. Thompson, Captain, USAF

AFIT-OR-MS-ENS-11-24

DEPARTMENT OF THE AIR FORCE
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THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Operations Research

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March 2011

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Abstract

Since the end of the Cold War, the number of weak and failing states has increased significantly. The United States (US) military has been deployed in multiple nation states in an effort to prevent these weak states from collapsing into chaos. This thesis explores one of the driving factors of state collapse, net migration, to gauge how US foreign policy might be employed to reduce the flow of people out of a country. To demonstrate the foreign policies and their effects, a pilot model was constructed using a system dynamics methodology. The Democratic Republic of Congo (DRC) was selected as a preliminary study for the model implementation.

This thesis examines three notional policies which could be implemented in the DRC: a reduction in the armed conflict occurring in the eastern provinces of the DRC, increasing the number of primary and secondary teachers in the DRC, and increasing the number of employment opportunities in the DRC. Interactions between different factors and drivers of migration are analyzed and included in the system dynamics model. Several scenarios are tested using this model. The results of these scenarios, as well as their implications for future policies, are detailed.

AFIT-OR-MS-ENS-11-24

To my wife for keeping everything under control at home.

To my kids for attacking me when I walk in the door.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Dr. Richard Deckro, for his guidance and support throughout the course of this thesis effort. The insight and experience was certainly appreciated. I would, also, like to thank my reader, Maj. JD Robbins, for his effort and help in making this a better product.

Michael J. Thompson

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I. Introduction

With the creation of USAFRICOM on 1 Oct 2007 (US AFRICOM Public Affairs Office, 2010), the United States underscored that events taking place in Africa were of strategic importance. The stated objectives of USAFRICOM include defeating Al-Qaeda and other terrorist organizations, halting transnational threats, countering the proliferation of weapons of mass destruction (WMD), and promoting a stable and secure Africa environment supportive of US policies (US AFRICOM Public Affairs Office, 2010). A stable government is a key component of these objectives (Wyler, 2008, p. 1). Policies and actions considered by the US should be evaluated *a priori* to determine how they will affect a particular nation's stability.

One of the most difficult aspects of decision making is understanding the environment in which a decision will be made. In the case of Africa, the relationships between tribes, vestiges of colonization, government bodies, insurgent forces, and international criminal organizations should be considered. Additionally, economic activity and population movement are useful in evaluating regional susceptibility to insurgent and criminal activity (Byman, Chalk, Hoffman, Rosenau, & Brannan, 2001). Using a holistic view of the environment will help investigate secondary, tertiary, and further effects of actions taken.

National Security Presidential Directive 44, issued by George W. Bush in 2005 states:

> "The United States should work with other countries and organizations to anticipate state failure, avoid it whenever possible, and respond quickly and effectively when necessary and appropriate to promote peace, security, [and] development" (Bush, 2005).

In support of this directive, this thesis examines the interactions between a nation's economy, education level, and armed conflicts within its borders, as well as the effects they have on international net migration. Additionally, it will examine the role US policies have on net migration. As a preliminary study, the Democratic Republic of Congo (DRC) was chosen due to the instability in the nation (The Failed States Index 2010, 2010); multiple insurgent groups operate within its borders, there exists a high occurrence of violent crime and human rights abuse, and the struggle over strategic natural resources is intense. To measure the effects of US policies on the stability of the DRC, a system dynamics model of the country was constructed. This model enables the study of the interactions between the economy, education, armed conflict, migration, and the repercussions of US policy in the DRC.

System dynamics is a method used to uncover and represent dynamic interactions in complex systems, first introduced by Jay Forrester in *Industrial Dynamics* (1961). Using a system dynamics (SD) approach enables the investigation of not only of initial effects of an action, but will track the interactions of these effects as they cascade across the country and internationally. It is important to note that the model proposed in Chapter III is designed specifically to model the net migration of the DRC. While insights gained may be extended to other nations, the caution should be exercised should model results be used for

countries other than the DRC. By using a SD modeling approach, models can be built that show the interactions and interdependencies of economics, education, insurgent activities, and transnational movement into and out of the DRC.

This thesis is organized as follows. Chapter II describes the current literature with respect to the importance and impact of nation stability, theories and factors of migration, the system dynamics methodology, and concludes with a brief history of the DRC and the current social and political situation in the country. Chapter III describes the proposed SD model, gives a detailed description of its construction, and the manner in which different US policies were assessed. Chapter IV provides the details of how the data was fitted and the results of regression. Chapter V contains the results of the constructed model, along with an analysis of the results of a set of notional actions. Chapter VI lays out the conclusions that can be drawn from the model and implications for the real world.

II. Literature Review

This chapter will examine the characteristics of unstable nations along with the impact these unstable regions have on the surrounding area and the world. After reviewing instability as a whole, a single factor of instability, migration, will be looked at in depth to determine its effectors, including the dynamic interactions of those effectors. The next section of the chapter studies the concept of system dynamics, a modeling technique that allows continuous, dynamic effects to be represented. System dynamics will be used to construct a model of human migration related to the Democratic Republic of Congo (DRC). The final section of this chapter contains a brief history and overview of the DRC to provide an understanding of some of the cultural issues involved in modeling migration in the DRC.

Nation Stability

In 2005, then-Secretary of State Condoleezza Rice wrote:

> "The phenomenon of weak and failing states is not new, but the danger they now pose is unparalleled….Weak and failing states serve as global pathways that facilitate the spread of pandemics, the movement of criminals and terrorists, and the proliferation of the world's most dangerous weapons." (Rice, 2005, p. B.07)

Additionally, failed states bring an increase in international drug and human trafficking and population displacement. While these problems can occur in strong states, weak states lack the capability to contain and deal with the problems, which can allow them to spread (Baker, 2007). Since the United States has a moral and strategic interest in preventing the problems that emanate from weak and failing states, it is in the US's interest to pay particular attention to the stabilization of these regions when engaging in international politics.

The difference between a failing state and a failed state is often a matter of time. Efforts should then be made to determine what a failed state did or did not do to change from a failing state to a failed one. In essence, what did the nation fail to do? Wyler states that a nation fails when it does not perform the functions of a government, which include providing peace and stability, effective governance, territorial control, and economic sustainability (Wyler, 2008). Williamson defines a failing state as one which lacks a professional police force and an independent judiciary, has poor health care, and has unregulated commerce (Williamson, 2007, p. 13). Williams combines these failures into two overarching failures: 1) failure to control and 2) failure to promote human flourishing (Williams, 2007, p. 37). He defines failure to control as being unable "to control actors and processes within a given territory," and failure to promote human flourishing as failing to provide public goods to the entire population (Williams, 2007, pp. 37-38). This thesis uses Williams' definition of state failure, with a failing state being one that the central government provides control and promotes human flourishing among friendly groups, but not hostile ones, and a failed state being one that cannot provide them for either friendly or hostile groups.

The classic example of a failed state is Somalia. Without a functioning central government for nearly 20 years, Somalia has become a haven to insurgent and criminal forces. Piracy, terrorists, poverty, slavery, and other human rights violations are prevalent throughout the country (Bureau of Democracy, Human Rights, and Labor, 2006). Increasing attention has been paid to Somalia recently as pirate raids from the country have increased, impacting international shipping and recreational sailing in the region. Preventing attacks has been difficult due to the Somali government's inability to

control its territory, while international law, the holding of hostages, and the prevention of non-combatant casualties impedes foreign warships from entering Somali territory to eradicate pirate havens. Piracy in the Somali region is estimated to have cost the international community between 7 billion and 12 billion US dollars (Gill, 2011). As evidenced from US actions during Operation RESTORE HOPE and the Battle of Mogadishu in the early 1990s, waiting until military action is required to prevent state collapse can be very costly, and not necessarily successful (Stewart, 2002). From the example of Somalia, it is evident that preventing state failure is a key component of international peace.

Determining the root causes of a state's failure is difficult at best and is generally different for each nation, but there are common themes that are prevalent. Baker maintains that one cause is a legacy of unresolved inequities, including colonial rule, corrupt elites, and superpower involvement (Baker, 2007). Williams summarizes the causes of state failure as a combination of bad leaders, predatory actors, bad economic policies, bad areas, and bad neighbors (Williams, 2007). Iqbal and Starr found that states transitioning to or from a democracy were more prone to state failure, as well as states experiencing violent conflict (Iqbal & Starr, 2007). The Fund for Peace uses twelve indicators to rate the criticality of state failure (The Failed States Index 2010, 2010). These are:

1) Mounting Demographic Pressures
2) Massive Movement of Refugees or Internally Displaced Persons creating Complex Humanitarian Emergencies

3) Legacy of Vengeance-Seeking Group Grievance or Group Paranoia

4) Chronic and Sustained Human Flight

5) Uneven Economic Development along Group Lines

6) Sharp and/or Severe Economic Decline

7) Criminalization and/or Delegitimization of the State

8) Progressive Deterioration of Public Services

9) Suspension or Arbitrary Application of the Rule of Law and Widespread Violation of Human Rights

10) Security Apparatus Operates as a "State Within a State"

11) Rise of Factionalized Elites

12) Intervention of Other States or External Political Actors

While there are a number of indicators or causes of a state's instability, this study focuses on the movement, or migration, of a nation's populace across international borders. It does not attempt to distinguish between forced migration and voluntary migration.

For the last several years, subject matter experts have come together to rank each nation on these criteria and judge the stability of that state. These rankings are then published as the Failed States Index (The Failed States Index 2010, 2010). A nation of particular interest is the Democratic Republic of Congo (DRC), which had the fifth worst rating out of the 177 countries measured in 2010. This ranking is even lower than both Iraq and Afghanistan. There are several features in the DRC of interest to US foreign policy: it has multiple armed groups operating within its borders, large rates of violent crime, large regions of ungoverned territory, severe human rights violations, and the

pillaging of valuable natural resources, including Uranium. A more in depth examination of the problems inherent in the DRC is conducted in a following section.

Migration

Theories of Migration.

When looking at human migration patterns, it has been suggested that there are three general types of migration. The first type is annual, or seasonal, migration. This is exemplified by field laborers traveling across a nation or continent finding employment harvesting agricultural products (Reichert, 1981). The second type is a forced migration, which occurs when people are unable to remain in their current region, despite their desires to remain. This type of migration typically generates international refugees and internally displaced persons (Davenport, Moore, & Poe, 2003). The third type of migration is a voluntary migration. A voluntary migration includes the movement of people who initiate the move themselves, whether it is looking for better employment or a better situation for themselves and their families (Davenport, Moore, & Poe, 2003). Reuveny views these types of migration as a cost-benefit analysis (Reuveny, 2005), with people deciding to migrate because the benefit outweighs the cost involved. It is important to understand the types of human migration in order to gain insight into why people do and do not migrate.

Since migration is an important factor of nation stability, it is helpful to know the causes of human migration so policies can be implemented that will counteract unwanted migration. Oruc describes the two main motivators of migration as a result of economics and conflict (Oruc, 2009). As the economic situation deteriorates in a region, people may desire to move elsewhere in an attempt to find a better financial situation for themselves

and/or their families, as exhibited in the United States during the migration out of the Dust Bowl during the Great Depression of the 1930s. A similar movement is encouraged in an area of conflict as refugees flee the region in order to find safety and security. Reuveny adds that environmental deterioration is another cause and catalyst of internal and international migration (Reuveny, 2005). Weather and climate change can spur both temporary and permanent migration as people are no longer able to subsist and thrive in their traditional home.

These factors not only cause migration, they in turn can be affected by migration. As migrants enter an area, tensions can arise between the migrants and the original residents. This tension could lead to conflict between the two groups, which in turn could lead to people migrating away from the area. Similarly, migrants using unsustainable agricultural methods could cause permanent environmental damage to an area, leading to a shift in the weather patterns of the area, which could then force migration away from the region. Because of the interplay between causes of migration and the movement of people, it is imperative to understand the relationships between the two in order to accurately model migration.

Over the years, there have been multiple theories of how best to represent the interplay between the economy and migration. The first theory is the neoclassical macro theory in which laborers will move to the areas where there is better employment and pay (Lewis, 1954) (Ranis & Fei, 1961) (Todaro, 1969). This theory represents the general laborer’s decision to migrate as a choice to move to the country which has the highest wages, which are interpreted to be the countries with the largest demand for laborers.

This theory assumes that there is an equilibrium point at which migration will cease when wages become equivalent in all nations.

The neoclassical micro theory builds upon the macro theory. Some authors have argued that rather than basing migration off of the gross wage rate in a country, the decision to migrate is an individual choice based upon the expected wage after factoring in costs of relocating to another area (Sjaastad, 1962) (Todaro, 1980). This theory explains why migration occurs into countries and regions where the Gross Domestic Product (GDP) is lower than the originating region.

In contrast to the neoclassical micro theory where the individual is the decision maker on whether or not to migrate, the "new economics of migration" theory argues that the decision to migrate is made by the family, and not an individual (Massey, Arango, Hugo, Kouaouci, Pellegrino, & Taylor, 1993). This theory states that families choose to have members of the family migrate in order to diversify the income to the family. This acts as a form of insurance against failures in the local economy and job market, as the household is receiving income from differing locations and occupations.

Push and Pull Factors.

In addition to the economic models of migration mentioned previously, a popular theory put forth by Lee (Lee, 1966) depicts migration as a result between various push and pull factors. Push factors occur in the current location of the potential migrant and encourage them to leave the area. Examples of push factors are unemployment, social exclusion, crime, violence, and housing conditions. Pull factors are traits of the receiving region that induce people to relocate to that area. Pull factors include family and friends in the area, labor demand, safety, public services, and cost of living. Additionally, this

theory recognizes that besides these push and pull factors, a person must overcome certain obstacles in order to physically move from one location to another. These costs could be the distance between the two locations, the cost of moving household goods, or immigration laws. In connection with these obstacles are personal traits that are specific to individuals and may cause them to migrate despite the irrationality of the decision based solely upon the push and pull factors.

Push factors are the attributes of a region that encourage people to leave (Lee, 1966, p. 50). Conversely, pull factors are those which draw migrants and refugees to a particular region or country. Main push and pull factors are unemployment rate, availability of educational opportunities, crime, violent conflict, family connections, and social and political exclusion. Understanding how each of these factors affects a person's decision to relocate themselves to another country is pivotal in determining future instability caused by migration.

Determining the effects of these factors is difficult due to the interrelationships between them. For example, a socially excluded group, that is, one which is disadvantaged by the local government (or believes itself disadvantaged), may turn to crime or violence in order to right its wrongs. This increase in criminal activity may persuade some business owners to relocate their businesses in order to prevent property damage and loss, as well as discourage new businesses from starting. The natural consequence of this is that unemployment increases, which in turn could lead to further social exclusion. Criminal activity, particularly violent crimes and armed conflict, creates refugees as civilians flee the hostile environment in which they reside. The refugees can then cause stress and tension in the areas they flee to, as they create a shift

in the population balance and seek employment. This stress and tension can then cause feelings of social exclusion in the refugees' destination region.   Due to the interdependencies of these factors, determining the specific cause of the resulting migration is a complex process.

A methodology developed by Jay Forrester known as system dynamics is quite useful in examining complex, interconnected problems. This thesis illustrates how a system dynamics model may be built and used to provide an estimate of net migration in a given region. A discussion of system dynamics and its uses is included in the next section.

System Dynamics

System dynamics (SD) was first introduced by Jay Forrester in his 1961 text *Industrial Dynamics*. Forrester defines a system as "a grouping of parts that operate together for a common purpose," (1968, p. 1.1) and dynamic as time-varying behavior (Forrester, Industrial Dynamics, 1961, p. 13). System dynamics, then, is the study of how a group of inter-related objects interact and vary over time. According to the System Dynamics Society, SD is "a methodology for studying and managing complex feedback systems." (System Dynamics Home Page, 2009) SD, initially introduced by Forrester as industrial dynamics, was originally applied to industrial processes to provide management with a tool to discern the interactions between time delays, amplification, and the structure of system components. Forrester then expanded on his work in *Urban Dynamics* (1969), the modeling of urban environments, and *World Dynamics* (1971), the application of the approach to global changes.   He showed that system dynamics, as it had come to be called, could be useful in modeling complex behaviors in fields other than

industrial processes. Since then, system dynamics has become widely used to study the dynamic interactions of complex systems. For example, Richardson, *et al*, used SD in their study of decision making and policy dynamics (1994), SD was central to Andrew Ford's work on environmental models (Ford, 2009), and Bhatt, *et al*, used a SD model to represent predicted maintenance of software systems (Bhatt, Shroff, & Misra, 2004).

The US Department of Defense has also used SD to model some of the complex problems it deals with. Grynkewich and Reifel (2006) used a system dynamics approach to model the funding of a terrorist organization. With their model they were able to show the interactions between group funding, group activity, and popular support. In addition, Pierson, *et al*, (Pierson, Barge, & Crane) was able to use a system dynamics model to represent the Army's method for performing counter-insurgency operations. In 2003 Ellis (Ellis, 2003) created a model framework using SD which represented the instabilities created in a region by the presence of criminal organizations. Crane (Crane, 2009) used a SD model to depict the different factors and interactions in gauging nation stability in the Democratic Republic of Congo. In their effort to analyze post-conflict reconstruction in foreign countries, Richardson, *et al*, used SD to model the complexities involved in rebuilding a society after a conflict. (Richardson, Deckro, & Wiley, 2004)

The System Dynamics Society refers to system dynamics as a methodology. They define the steps of this methodology as:

1) identify a problem,

2) develop a dynamic hypothesis explaining the cause of the problem,

3) build a computer simulation model of the system at the root of the problem,

4) test the model to be certain that it reproduces the behavior seen in the real world,

5) devise and test in the model alternative policies that alleviate the problem, and

6) implement this solution.

While this process is typical of a modeling approach, the uniqueness of the SD method lies in the dynamic hypothesis created in the second step. This dynamic hypothesis consists of depicting the interactions between parts of the system as differential equations, which are estimates of the "flow" in the system. These equations allow for the system to be modeled as a continuous-time system, and allow the system to feedback upon itself while measuring the current positions of objects to control the system behavior. Properly applying this methodology often leads to each step being executed multiple times as hypotheses and models are formulated, tested, verified, and validated.

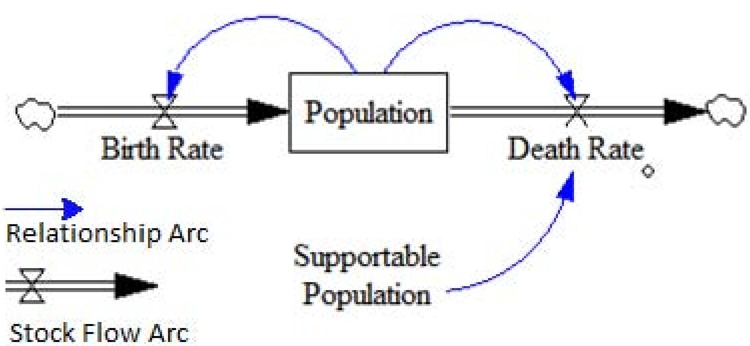
A SD model is a representation of the feedback loops in a system. A feedback loop is a system characteristic in which future states are derived from current states. Unlike a discrete event model, a SD model is assumed to change continuously over time rather than at discrete events. The nature of the feedback, whether positive or negative, will determine how the system reacts to a change in the system. Negative feedback loops will create an equilibrium-seeking behavior in the model, whereas a positive feedback loop will cause the system to grow continually (Forrester, 1971, p. 19). The continual growth generated by positive feedback loops is often undesirable, as it leads to unstable systems and models. Negative feedback loops are the key to the implementation of SD. They provide balance to the system by controlling the change in model objects, which produces reasonable, realistic outcomes in the system.

To represent these feedback loops, SD uses stocks (or levels), rates, variables, and arcs. A stock is a quantity of an object that will change over time, and is generally modeled as the stock name surrounded by a box. Rates are objects that control the change in a stock, and are also referred to as inflows and outflows, depending on how they change the stock. Rates are typically depicted as a double-lined arrow with an hourglass symbol. They may be constant or they may be a function of the levels and variables in the model. A variable is a system parameter that affects, and is affected by, the system, but does not have rates continually changing its value. A variable is represented simply by the variable name. Arcs are used in SD modeling to signify relationships between objects in a model. Arrows are used to represent arcs and connect an object to its dependent object. Figure 1 contains a simple SD model depicting these attributes of a SD system.

A simple example of this control is the birth and death rates of a population (see Figure 1). Increasing a population size will increase the birth rate of the population; an increased birth rate will lead to a further increase in the population. This example of a positive feedback loop would produce an exploding population size without any constraints. However, the negative feedback loop caused by the death rate tempers this process. As seen in Figure 1, the death rate of a population is dependent upon the population size, as well as the size of the supportable population. When a population increases past the capacity of its environment to sustain it, the death rate will increase due to competition for resources. Eventually, the death rate will become greater than the birth rate, which will lead to a decrease in the population. As the population is reduced below the environment's capacity, competition for resources will be reduced, the death rate will

decrease, and the population will again increase once the birth rate is greater than the death rate. This cycle will repeat itself, potentially creating an oscillation of the population about the environmental capacity as it approaches a steady state. The balancing influences of birth and death rates and their feedback loops allow a population to sustain itself. If they are out of balance, then the population could grow or shrink to unsupportable levels. Accurate representation of these feedback loops is a key component of successful SD modeling.

Figure 1: System dynamics model of population



Since SD deals with studying feedback systems, it is useful when working with a system that derives, or predicts, its future state from its current or past states. In addition, as the name implies, system dynamics works well for systems that change over time. Thus, an assembly process with a fixed speed and process would be better represented using another method, such as a discrete event simulation. Modeling areas that SD has been effective in representing are biological and environmental systems, supply-chain management, social sciences, dynamic decision making, and military force management. (System Dynamics Home Page, 2009)

As with all modeling approaches, the question of how to verify and validate the constructed model is a recurring problem. Verification is defined as "the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specifications" (Verification - DoD Dictionary of Military Terms, 2010). It requires the model builder to ensure that the outputs are reasonable given the inputs into the system. Conceptually, this step is equivalent to checking your math, or debugging your program. Once the designer is satisfied the model operates as designed, the next step is to validate the model.

As defined by the DoD, validation is "the process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model or simulation" (Validation - DoD Dictionary of Military Terms, 2010). In other words, validation is making sure that the model performs the function for which it was originally designed, or, put another way, a valid model is one that "is good enough for its purpose" (Coyle & Exelby, 2000, p. 28). In building a valid SD model, the developer should be concerned with the users' purpose of the model and strive to accomplish it. The purpose of modeling a system is to gain insight into it. If the model builder does not know what insight the user hopes to gain from the model, the model is useless to the user and it will not be used.

In their paper "Tests For Building Confidence In System Dynamics Models", Forrester and Senge (Forrester & Senge, 1980) laid out several tests that are useful in establishing the validity of SD models. The tests proposed by Forrester and Senge are largely subjective in nature, and fall within three main areas: structural tests, behavioral

tests, and relationship tests. Shreckengost (DYNAMIC SIMULATION MODELS: How Valid are They?) examined these tests and gave further clarification on each.

Structural Tests.

Ensuring the validity of the model structure is necessary, since the model performance is based upon its structure. Each component of the model should be representative of an aspect of the real world system. There are several tests that help ensure this:

> 1) Model Parameter Tests – Parameter values should be consistent and reasonable with the data available (Shreckengost, p. 2). The parameters of the equations used in the model should be examined by the subject matter experts (SMEs) and users to ensure that they are consistent with data and user inputs available.
>
> 2) Boundary Adequacy Test – Ensure the boundaries built into the model are the same as the boundaries of the system to be examined (Shreckengost, p. 3). The model boundaries are the limits placed upon the design of the model. For example, a model designed and built to model the population of Los Angeles would fail the Boundary Adequacy test if it was being used to model the population of the United States.
>
> 3) Extreme Conditions Test – Testing the extreme conditions can reveal logical errors in the model design (Shreckengost, p. 3). This test will show model performance over the range of input values.

Behavioral Tests.

Behavioral tests examine the behavior of the model to make sure the model behaves, or produces the output, in a similar manner as the real system.

> 4) Behavior Replication Test – The behavior of the model should parallel the behavior of the actual system being studied (Shreckengost, p. 4). Levels and rates in the model should be parallel to those of the real system, i.e., if an action causes the real system rate to increase, the same action should not cause the model rate to decrease. Does the model look like the real system?
>
> 5) Anomalous Behavior Test – "When model behavior does not replicate the behavior of the real system, model structure, parameter values, boundaries, or similar factors are suspect. Something may have been omitted, improperly

specified, or assigned incorrect values” (Shreckengost, p. 5). If an anomaly occurs in the model, when fed with historical data, there is reason to suspect that the model contains an error, which would need to be addressed.

6) Behavior Sensitivity Test – The model should exhibit sensitivity to changes consistent with that of the real system (Shreckengost, p. 6). This means that reactions in model should be of the same magnitude and direction as the real system. This would require real world data to compare against, and thus may not be feasible to test future changes, if similar ones have not been performed in the past.

7) Behavior Prediction Test – Model reacts to changes in the same manner as existing systems reacted to the same changes. (Shreckengost, p. 6)

Relationship Tests.

Relationship tests are used to assess the applicability of the model to other systems. While these tests do not necessarily help validate the model for its particular purpose, if passed, they can increase the usefulness of the model to the user.

8) Family Member Test – The model will gain extra usefulness if it can be applied to a family of systems (Shreckengost, pp. 6-7). An example of a possible family model would be one that was built to model the flow of refugees in Rwanda, but could also be applied to refugee situations in other parts of Africa.

9) Behavioral Boundary Test – Ensure the model boundaries are adequate to deal with any excursion that will be explored (Shreckengost, p. 7). This involves, again, knowing the purposes of the model users. Knowing what they are interested in, and the insight they would like to gain from the model will allow the model builder to the model boundaries are sufficient to the task. Passing this test allows the model to not only be used to model the current system, but also deviations from the current system that the user might be interested in exploring.

Conducting these tests on the model will give insight into its usefulness. They will also help refine the model, and eliminate errors and discrepancies that have occurred. While these tests should be performed by the author of the model, they should also be performed by the user and SMEs to ensure that all requirements are met, as well as to secure user trust in the model.

The previously mentioned tests form the core of SD model validation in practice. Many SD practitioners have upheld these tests, with a few additional tests proposed (see Coyle & Exelby (2000, pp. 32-36) for a detailed examination of papers dealing with SD validation). One such test is the Turing Test as proposed by Barlas (Barlas, 1996). This involves having a person familiar with the real system examine outputs from the real system and the model. Passing the Turing Test occurs when the examiner is unable to tell which outputs came from which source.

Another method to test and improve the validity of complex models was proposed by John H. Miller (Miller J. H., 1998). In his paper he discusses the use of Active Non-linear Tests (ANTs) to test the model structure for weaknesses. He proposes the use of a non-linear algorithm to stress the model by seeking to maximize the difference between the expected result of the original SD model and results obtained by reasonable perturbations of the model (Miller J. H., 1998, p. 820). The results of this test can then be used to make adjustments to the model to eliminate unreasonable fluctuations that were discovered.

In the ideal case, all of the tests would be performed and passed; in practice, however, it may not always be possible to perform all of these tests, or perform all of them on all parts of the system, due to resource constraints and deadlines. Verifying and validating sections of the model may be necessary if there is insufficient data to support the validation of the overarching model. The inclusion of specific tests in the validation process depends largely upon what data is available and what is known about the system. For example, if the internal workings of a system are unknown, then tests that study the internal behavior of a system will be irrelevant and tests examining the end result will

have to be relied upon. Conversely, if the details of the system are available, then tests should be used which confirm all points of the model behave in the same manner as the real system. Communication with the user is key is developing a valid model, since in the end, if the user does not believe that it is valid and doesn't trust it, then it isn't a valid model and will not be used.

In order to fully validate an SD model, several statistical methods should be used. Real world data will need to be fitted to dynamic, differentiable equations so the performance of the model with real data can be observed. Several tests have been developed to judge the fit of data, including the Chi-Square test, Kolmogorov-Smirnov (KS) test, and the Anderson-Darling (AD) test. While the KS and AD tests are considered more powerful tests, users may be more familiar with the Chi-Square test (Miller J. O., 2010), thus the "best" test may be the one in which the user has the most confidence. If there is a small data sample size, then the AD or KS tests are the more powerful tests, as they are accurate with small samples, unlike the Chi-Square test.

Aside from testing the model with real world data, tests should be performed using differing input values. A design of experiments (DOE) approach is useful in determining which factors, and at which levels, should be included in the model tests. When the tests have been performed, an analysis of variance (ANOVA) should be performed to determine which factors, of all the ones being tested, are causing the variations in the model results. The ANOVA performs an F-Test on the results to determine if the factors used have significant impacts on the result. The ANOVA can also provide insight into higher order interactions between factors, which knowledge can be used for further refinement of the model.

Ideally, the model presented in this study would be verified and validated with all of the aforementioned tests. However, due to data limitations and resource constraints, verification and validation is performed using the nine subjective tests summarized by Shreckengost. To determine interactions between factors, a regression was performed on the data and an ANOVA was used to verify the factors had a significant impact on the result. The results of this regression is presented in Chapter IV.

The Democratic Republic of Congo

To understand the unique and difficult challenges that the DRC faces as a nation, it is important to have a knowledge of the history of the country, as well as the struggles the people face in their lives today. This knowledge will serve as a foundation for building a model to represent the net migration in the DRC.

The modern history of the DRC begins in 1871 when Henry Morton Stanley began the first European exploration of the Congo River basin (Dugard, 2003, p. 119). Upon his return to Europe, he entered the employ of the King of Belgium, Leopold II, and returned to the Congo to establish a Belgian colony in the region (Heale & Lin, 2010, p. 25). Using his skills in playing one tribe off of another and modern weaponry, Stanley was able to open up the Congo for colonization by King Leopold within three years (Hochschild, 1999, p. 87).

Before sending Stanley to colonize the Congo, Leopold began striving to acquire colonies for Belgium. In 1885 he used his skills in politicking to have the international community bestow upon him the private ownership of the Congo region, and it became a private colony of the crown known as the Congo Free State. Ostensibly, Leopold was to use his position to assist in the “civilizing” of the Congo natives, though in actuality, the

Congo became nothing more than a money making enterprise for the king, at the expense of the African natives (Hochschild, 1999, p. 87). By brutalizing and enslaving the local populace, Leopold began the systematic pillaging of the natural resources, particularly ivory and rubber, of the Congo Free State. Despite the attempts of a small number of travelers decrying the situation in the Congo, the international furor did not put a stop to Leopold's exploitation until 1908, when the Parliament of Belgium annexed the Congo Free State. By that time, it is estimated that 5 to 12 million Congolese were killed under Leopold's "civilizing" rule (Hochschild, 1999, p. 3) (Encyclopaedia Britannica, 2011).

Unfortunately, after control of Congo shifted to the Belgian government, daily life did not improve significantly. Body mutilation of the natives was discontinued, but the majority of the regional administrators remained the same and the system of forced labor, conscription, and beatings continued (Hochschild, 1999, pp. 278-279). It was common practice for a village chief to be paid for mine workers, and the laborers he would send, tied together, were those he disliked or who threatened his authority (Hochschild, 1999, p. 279). The tradition of forced labor and exploitation of the native population continued until the Belgian Congo gained its independence on June 30, 1960.

After gaining independence, the DRC quickly descended into chaos. Within six months of gaining independence, four opposing regimes were established within what had once been the Belgian Congo: President Joseph Kasa-Vubu and Colonel Joseph Mobutu in western Congo, supported by the US and Western powers; Prime Minister Patrice Lumumba in northeastern Congo supported by the Soviet bloc; secessionists in southern Kasai Province; and secessionists in Katanga Province led by Moise Tshombe, supported by the Belgians (Meredith, 2005, p. 110). Lumumba was captured and killed

in 1961 and the UN ended the revolt in Katanga in 1963. However, a massive rebellion broke out in the former Lumumba stronghold in the northeast in 1964 and the Congolese government lost control of nearly half the country (Meredith, 2005, p. 114). The US and Belgium sent forces to the area to protect US and European citizens caught in the conflict and to prevent the dissolution of the country. The rebellion was successfully quelled, but political infighting continued until General Mobutu, the Army Chief of Staff, led a military coup in 1965 and took control of the government (Meredith, 2005, p. 115).

Following his takeover of the government, Mobutu began a systematic effort to remove political rivals and crush all rebellions which flared up. Within five years he had gained some level of control over most of the country (Meredith, 2005, p. 294). Mobutu changed the name of the country to Zaire and ruled it for the next 30 years while accumulating a personal fortune estimated at $5 billion (Hetzer, 1987). Mobutu's rule was a model of corruption and control over the political machine. Political rivals were publicly executed and officials in the government were frequently rotated to prevent subordinates from gaining too much power. Foreign owned businesses were seized and given to close friends and family members (Meredith, 2005, p. 298). He built lavish palaces for himself in his own country, as well as throughout Europe.

Throughout his rule, Mobutu was treated as an ally and friend to the United States and its presidents. Zaire was seen as a bulwark to prevent the spread of communism in Africa, and received a number of favorable deals from the US to keep Mobutu's support (Meredith, 2005, pp. 294-295). Along with the political reasons for allying with Mobutu, the US and the rest of the world had an interest in the vast natural resources within Zaire's borders. Aside from the uranium mines that supplied material for nuclear

weapons, the Congo also contains vast amounts of gold, diamonds, copper, tin, and several rare earth metals that are used in modern electronic devices. However, despite these vast natural resources, the corruption of Mobutu's regime prevented this wealth from reaching the vast majority of the population. During Mobutu's rule, average income per capita never climbed over $500 (2010 US dollars) per year (The World Bank, 2011). The extreme poverty of the people under Mobutu's rule, coupled with the corruption and the oppression of those deemed political dissidents, caused sentiments of unrest to grow among the populace.

After the collapse of the Soviet Union, maintaining the alliance with Mobutu ceased being a necessity and Western powers began pushing Mobutu to make political reforms and eliminate corruption (Meredith, 2005, p. 391). During the last five years of his rule, dissident groups began to gain strength, and Mobutu was forced to give concessions to opposing groups and allow multi-party elections. In 1994 an estimated one million Hutu refugees and perpetrators of the Tutsi genocide in Rwanda entered eastern Zaire after fleeing from Rwanda (Meredith, 2005, p. 522). The Hutu continued launching attacks on Tutsi populations in eastern Zaire and Rwanda until 1996, when Rwanda and Uganda sent forces into Zaire with the purpose of halting the attacks and ending Mobutu's rule (Meredith, 2005, pp. 531-532). In an effort to appease the international community, the forces were placed under the command of Laurent-Desire Kabila, an anti-Mobutu former guerilla operating in eastern Zaire (Meredith, 2005, p. 531). By the end 1996, the invading forces had sufficient strength that the eastern half of Zaire was captured by rebel groups (BBC News, 2010). In 1997 the rebels managed to overthrow Mobutu's government in Kinshasa (BBC News, 2010), install Laurent Kabila as

president, and change the name of the country back to the Democratic Republic of Congo.

The following years saw multiple wars and conflicts being waged as the DRC's neighbors attempted to gain control and influence over the vast natural resources within its borders. In 2006, a new constitution was accepted, bringing hope of greater stability in the country. However, there are still armed militias and insurgent groups, located mainly in the eastern provinces of the DRC, which have resisted integration into civilian life and continue to execute assaults on the local populations. Government troops have been sent to the area to quell the insurgents, but lack of logistical support to the troops has caused them to take what they need/want from the populace they were sent to protect (Kelly, 2010). Currently the United Nations largest mission, MONUSCO, is in eastern DRC in an effort to protect civilians and prevent gross human rights violations that have been endemic in the region. Unfortunately, violent assaults and rapes are committed almost daily, some only miles from UN garrisons (Kron, 2010).

The ineffectiveness of the government of the DRC to control the violence and crime committed within its borders and by its own troops strongly indicates that this is a country on the brink of failure. The corruption existent throughout the government and its military has created an environment where businesses do not flourish and the populace lives in fear and poverty. The result of this is high unemployment, violent conflict in large portions of the country, and a high occurrence of human rights violations. In short, the DRC is an undesirable country of destination for migration or living, in current situation. This thesis examines several courses of action and their effectiveness at reducing migration in the DRC, thereby increasing the country's stability. The following

chapter details the methodology used to construct a system dynamics model of the net migration in the DRC, as well as the notional scenarios that were used to measure the effectiveness of possible US actions.

III. Methodology

In an effort to gain insight into one aspect of the effectors of instability in a nation, this study develops a preliminary system dynamics model to examine the effects policy changes have on net migration in the Democratic Republic of Congo (DRC). This chapter is organized as follows. The purpose of the model is stated along with notional courses of action which could be simulated with the model. The data requirements of the model are established, and the data sources are listed. The construction of model using the literature and regression analysis is described. The method for verifying and validating the model is defined. A design of experiments is then created to test the effectiveness of notional courses of action. The concluding section establishes six scenarios which model notional policies which could be enacted in the DRC.

Model Purpose

It is widely accepted that state failure is a very complex issue with multiple causes and interacting effects. This study examines one factor of state failure, net migration, to determine the effectiveness of US foreign policy actions in ameliorating outward migration. A study of the literature and US policy towards the DRC gave rise to three questions this study strives to address. These questions are:

1) United Nations Organization Stabilization Mission in the Democratic Republic of the Congo (MONUSCO) has tasked the US with the project of road construction and maintenance (MONUSCO, 2010). How would jobs created by this effort affect net migration?

2) According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO), sub-Sahara Africa needs 1.6 million more primary education teachers to make primary education available to everyone (UNESCOPRESS, 2006). How would an increase in the number of primary and secondary teachers affect net migration?

3) The US has accepted the task of increasing community security and reintegrating ex-combatants in the DRC (MONUSCO, 2010). How will reducing the size and scope of the conflict in the DRC affect net migration?

With the completion of the model definition and purpose, sources were sought to provide data to be regressed and analyzed.

Data Requirements

Databases available from the World Bank (WB) provided much of the data regarding the demographics, economy, and education in the DRC. The WB data has been vetted by the United Nations (UN) and is a primary source for certain UN reports (UNDP, 2010). Additional demographic data was provided by UN organizations and the US Census Bureau (USCB). Data regarding the intensity of armed conflict in the DRC was taken from the Political Instability Task Force (PITF), a Central Intelligence Agency (CIA) funded organization (Center for Global Policy, 2010). Note that the data provided by the PITF is discrete, categorical data. In an effort to mitigate the inaccuracies involved with using discrete values in a continuous model, the data provided by the PITF was modeled as factors controlled by the user. Table 1 lists the input variables needed to execute model and the data source used to drive the DOE and scenario test cases. For two of the variables, Labor Force and Population (Percentage, 15+), the age of fifteen was chosen as the delimitating value because this is the UN and WB recognized age to estimate when a person enters the workforce. While this age may be inappropriate for a specific country (possibly including the DRC) it is an internationally recognized standard. Table 2 lists the output variables produced by the model, as well as the source of the data used to fit relationships. These tables are repeated in Appendix A.

Table 1: Input Variables and Sources

Factor	Symbol	Description	Source
15+ Population	PW	The percentage of people over the age of 15 in the DRC	WB*
Life Expectancy	LE	The life expectancy at birth for the DRC	USCB*
Magnitude Fighting	MFi	A dummy variable, 0-4, that represents the number of combatants or activists participating in an uprising	PITF**
Magnitude Fatalities	MFa	A dummy variable, 0-4, that represents the number of deaths caused by a conflict	PITF**
Magnitude Area	MA	A dummy variable, 0-4, that represents the land area size where the conflict is occurring	PITF**
Jobs Created	JC	The number of jobs (thousands) created in the DRC by US policies	N/A***
Additional Primary Teachers	APT	The number of primary teachers (thousands) created in the DRC by US policies	N/A***
Additional Secondary Teachers	AST	The number of secondary teachers (thousands) created in the DRC by US policies	N/A***

* These variables were used in the model regression and are not altered in the scenarios

** These variables were used in the model regression and are altered in the scenarios

*** These variables were not used in the model regression and are altered in the scenarios

Note that the definitions Unemployment, Change in Unemployment, and Labor Force are not those used by the WB. Since the unemployment rate in the DRC was unavailable, a proxy measure of unemployment was established by using the WB statistic of Employment to Population Ratio (15+, total (%)). The Labor Force was then calculated by multiplying the size of the population 15+ by the employment ratio. Thus Labor Force in the model represents the number of people actually employed in the DRC.

Table 2: Model Variables and Data Sources

Factor	Symbol	Description	Source
Population (Total)	P	Millions of people in the Democratic Republic of Congo	WB
Net Migration	NM	The number of people per million per year who enter (positive value) and leave (negative value) the DRC	WB
Unemployment	U	The percentage of the population 15+ who are unemployed in the DRC	WB
Change in Unemployment	CU	The change in the unemployment percentage in the DRC in a year	WB
Labor Force	LF	The number of people (in thousands), age 15+, who are employed in the DRC	WB
GNI per Capita	GpC	The Gross National Income (Purchasing Power Parity, or PPP) per capita in the DRC, measured in 2010 US$	WB
Education Index	E	0 to 1 value used by the UN to represent educational opportunity and expectations in the DRC	UNDP
GNI	GNI	The Gross National Income (PPP) of the DRC measured in millions of 2010 US$	WB
Birth Rate	BR	Number of live births per thousand per year in the DRC	WB
Death Rate	DR	Number of deaths per thousand per year in the DRC	WB
Primary Students per Teacher	PSpT	The number of primary students per primary teacher in the DRC	WB
Primary Pupils	PP	Number of primary students in the DRC measured in thousands	WB
Primary Teachers	PT	Number of primary teachers in the DRC measured in thousands	WB
Change in Primary Teachers	CPT	The increase or decrease in the number of primary teachers in the DRC, in thousands per year	WB
Secondary Students per Teacher	SSpT	The number of secondary students per secondary teacher in the DRC	WB
Secondary Pupils	SP	Number of secondary students in the DRC measured in thousands	WB
Secondary Teachers	ST	Number of secondary teachers in the DRC measured in thousands	WB
Change in Secondary Teachers	CST	The increase or decrease in the number of secondary teachers in the DRC, in thousands per year	WB
Refugees Out	RO	The number of people from the DRC, in thousands, who are refugees or in refugee-like situations living outside the DRC	UNHCR

WB: The World Bank (http://data.worldbank.org/indicator)
UNDP: The United Nations Development Program (http://hdrstats.undp.org/en/tables/default.html)
UNHCR: The United Nations High Commissioner for Refugees (http://apps.who.int/globalatlas/DataQuery/default.asp)
PITF: Political Instability Task Force (http://www.systemicpeace.org/inscr/inscr.htm)
USCB: United States Census Bureau International Database (http://www.census.gov/ipc/www/idb/country.php)

Table 3: PITF Data Value Definitions

Factor Value	Magnitude Fighting (Number of rebel combatants or activists)	Magnitude Fatalities (Annual number of fatalities related to fighting)	Magnitude Area (Portion of country affected by fighting)
0	<100	<100	less than one-tenth of the country and no significant cities are directly or indirectly affected
1	100 to 1000	100 to 1000	one-tenth of the country (one province or state) and/or one or several provincial cities are directly or indirectly affected
2	1000 to 5000	1000 to 5000	more than one-tenth and up to one quarter of the country (several provinces or states) and/or the capital city are directly or indirectly affected
3	5000 to 15000	5000 to 10000	from one-quarter to one-half the country and/or most major urban areas are directly or indirectly affected
4	>15000	>10000	more than one-half the country is directly or indirectly affected

As noted earlier, the data drawn from the PITF used discrete values on a 0-4 scale to represent the Magnitude Fighting, the Magnitude Fatalities, and the Magnitude Area. Table 3 shows the ranges of each of the variable values. These scales are discrete and non-linear in nature; unfortunately the precise number of combatants and fatalities was not given. Including this type of data in as a regression model introduces inaccuracies, since regression assumes the variables are continuous. Regressing the categorical PITF values to represent violence is a deficiency of the model; using continuous data for violence variables would yield more accurate results. In an effort to mitigate the negative effects of the categorical data, the PITF data was used as independent variables in the

regression analysis. Should continuous violence data be made available, it should considered in the model.

Model Construction

After the data was gathered from the various sources, it was necessary to fit the relationships and effects the different variables had on one another in relation to modeling migration. Using the important factors of migration drawn from the literature, likely relationships were predicted to represent the expected interactions. The main driving factors considered were violence, the economy, and education. Each of these main factors was modeled by additional factors in an effort to gain further insight into significant effectors of net migration.

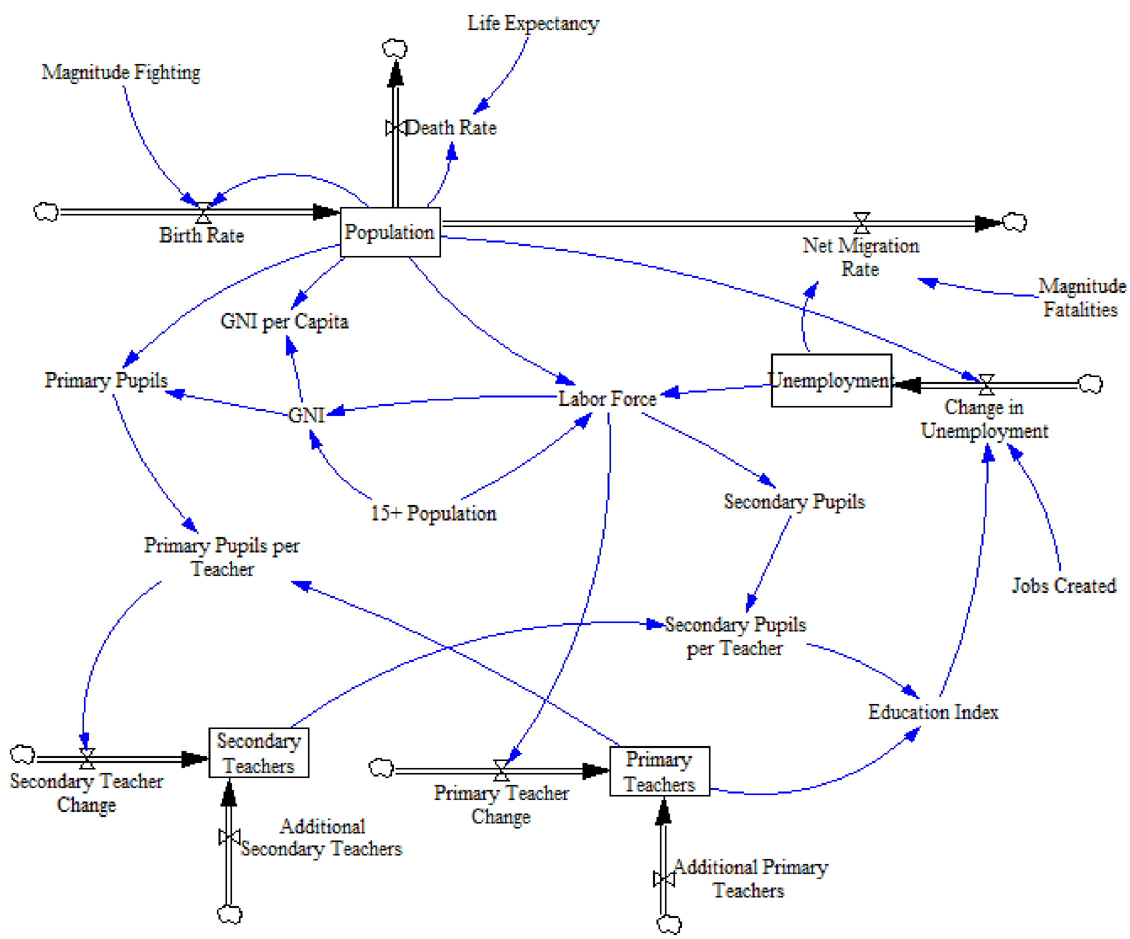
The JMP 9.0 software package was used to perform linear and non-linear regressions to determine the significant relationships of the model, and the impact they have on net migration. A stepwise least squares regression was performed on each output variable using likely factors as the independent variables. Factors to remain in the model were required to have p-values less than 0.05. Once significant variables were established, a standard least squares regression was performed to verify the variables passed a t-test at the 0.05 level. In addition multi-collinearity between independent variables was reviewed. If an independent variable failed the t-test, or high multi-collinearity was found, a stepwise regression was performed with the variable removed and the process repeated.

Of interest was the finding that the number of fatalities and the area of the conflict did not have a statistically significant impact on any output variables for the limited data set used. Therefore, these variables were not included in the SD model and were not

considered further in the analysis. Since these variables have been considered significant in other studies, the results developed in this study should be considered illustrative. If more data regarding armed conflict in the DRC became available, future research should be done to analyze the impact of violence on net migration in the DRC.

The regression equations are detailed in Chapter IV. Using the regression equations developed, as well as the knowledge gained from the literature search, the Migration Model of the DRC (MMDRC) model was built using the VenSim PLE software, a SD model of migration in the DRC. Figure 2 shows a diagram of the MMDRC. The model diagram is also contained in Appendix B.

Figure 2: Diagram of MMDRC



Model Initialization

Using the literature search and the relations developed with the regression models provides the relations for the SD model. Figure 2 gives a visual representation of how the variables relate and interact with each other. By visual inspection of Figure 2, it can be seen which variables are user input driven, require an initial value, or are pure output variables. In the MMDRC all variables with no incoming relationship arcs require the user to provide input for each year of the simulation, all stock variables in the model require an initial value, and variables with incoming relationship arcs are pure output variables. Variables which require yearly user input are Life Expectancy, 15+ Population, Magnitude Fighting, Jobs Created, Additional Primary Teachers, and Additional Secondary Teachers; stock variables are Population, Unemployment, Primary Teachers, and Secondary Teachers; all others are pure output variables. It is assumed that various courses of actions can be taken to affect the variables which require yearly user input. For example, it follows from the literature and the regression analysis that GNI is affected by 15+ Population and Unemployment, and it affects Primary Pupils, GNI per Capita, and Net Migration Rate.

As MMDRC is constructed to analyze the impact of decisions over time, it is initialized with estimated 2011 values. To estimate the 2011 initial stock values and the future values for 15+ Population, MatLab v7.11.0 (R2010b) was used to perform a simple linear regression using time as the independent variable. All recorded data from 1990 to 2010 for each variable from the previously cited sources was used in the regression. The future values for Life Expectancy were taken from projections for the

DRC made by the US Census Bureau (US Census Bureau, 2010). Table 4 contains the values used to initialize the stock variables of the MMDRC for 2011, and the future values of Life Expectancy and 15+ Population for 2012 – 2016. The values for Population, Unemployment, Primary Teachers, and Secondary Teachers for the years 2012 and beyond result from interactions in the model.

Table 4: Projected Values for Model Inputs

Variable	2011	2012	2013	2014	2015	2016
Life Expectancy	55	56	56	57	57	57
15+ Population	53.9	54.2	54.5	54.7	55	55.3
Population	69.4	--	--	--	--	--
Unemployment	33.4	--	--	--	--	--
Primary Teachers	298.1	--	--	--	--	--
Secondary Teachers	230.3	--	--	--	--	--

Verification and Validation

As the regression models were constructed, F-tests were performed on each equation to verify its significance at the 0.05 level. The null hypothesis for the F-test is that a better F-value can be obtained by random chance if the model fits no better than the overall response mean. A test result of less than 0.05 indicates that there is at least one significant factor contained in the model. As an additional step in the verification and validation (V&V) process, the subjective tests described by Shreckengost (Shreckengost) were performed on the MMDRC to test its functionality. Additionally, a design of experiments (DOE) was created to verify the impacts the user defined input variables had on the output variables. The results of the V&V process are discussed in further detail in Chapter IV.

Design of Experiments

In order to measure the effectiveness of various proposed policies, a design of experiments (DOE) was performed to test the input factors at different levels. Table 5 shows the factors that were tested, along with the low, middle, and high levels for each. For the categorical values of Magnitude Fighting and Magnitude Fatalities, each of the values 0 through 4 was included in the design. The high level for Jobs Created was estimated as the number of workers needed to build the proposed Grand Inga Dam in northwestern DRC. The estimated number of workers needed was based upon the number of workers who worked on the Three Gorges Dam, constructed in China. Since an estimated 60,000 workers were used to complete the Three Gorges Dam (Hays, 2010), and the proposed Grand Inga Dam in the DRC is projected to be an even larger undertaking, the number of jobs created in working on the Grand Inga Dam was estimated at 70,000. The high value for Additional Primary and Secondary Teachers was estimated using 5% and 3%, respectively, of the number of education majors in the US who graduated in the 2007-2008 academic year, which was 103,000 (National Center for Education Statistics, 2009). These are notional values of how many teachers could be sent to the DRC. It is recognized that a major in education is not required to teach primary and secondary students in the DRC.

Using the values in Table 5, a mixed design combining three 2-level variables with five midpoints (the continuous variables), and two 5-level variables (the categorical variables) was generated to test the full range of parameter values while preventing the

confounding of main effects. This resolution III design requires 25 runs for the analysis and is shown in Appendix C. The results of the DOE are examined in Chapter V.

Table 5: Input Varible Levels for DOE

Variable	Low Value	Mid Value	High Value
Magnitude Fighting	0	-	4
Magnitude Fatalities	0	-	4
Jobs Created per Year (Thousands)	0	35	70
Additional Primary Teachers per Year (Thousands)	0	2.575	5.15
Additional Secondary Teachers per Year (Thousands)	0	1.545	3.09

Test Creation

Following the construction of the functional model, test cases were defined to test the impact of US policies on net migration in the DRC. The purpose of these scenarios is to analyze the effects policies have if they are executed in multiple years, as well as to determine if notional US policies could affect significant changes in the migration rate in the DRC. These test scenarios were derived from current US and UN projects and objectives in the DRC and the author’s estimations of how these projects will proceed in the future. Results from each scenario are simulated for five years following initialization and are analyzed in Chapter V.

Scenario1

Scenario 1 was established by initializing all input values at their projected 2011 levels. The input values are held constant, allowing natural growth for the next five years. The input driven variables, Life Expectancy and 15+ Population, continue to change according to the estimates obtained from MatLab, as previously mentioned. All other

inputs are held constant. As indicated by a Magnitude Fighting value of 3, there are an estimated 5,000 to 15,000 rebel combatants involved in the conflict each year. The Magnitude Fatalities value of 2 indicates there were between 1,000 and 5,000 combat related deaths. Table 6 shows the settings used for the baseline scenario.

Table 6: Scenario 1 Inputs – Inputs Constant

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	0	0	0
1	3	2	0	0	0
2	3	2	0	0	0
3	3	2	0	0	0
4	3	2	0	0	0
5	3	2	0	0	0

Scenario 2

The second scenario tests a situation in which security forces are able to successfully quell the insurgent activity. A steady decrease in the Magnitude Fighting and the Magnitude Fatalities is projected while Additional Primary Teachers, Additional Secondary Teachers, and additional Jobs Created remain constant at 0, meaning these teachers and jobs in the DRC are not considered to be directly affected by this policy. Whatever changes occur in the other variables are endogenous to the model. In year 1, the number of insurgents drops below 5,000, but remain above 1,000. The fatalities occurring also decreased to the 100 - 1,000 range of deaths. In year 2, the insurgents continue to lose forces and their numbers fall below 1,000 combatants. In year 3 the fighting is further quelled as the number of fatalities falls below 100. In year 4 the number of insurgents falls below 100 and are held below 100 in year 5 as well. It should

be noted, however, that no specific actions are detailed to execute these reductions. The estimates are merely provided to test the model and judge the potential effect of a reduction in violence, given appropriate actions have been designed. Table 7 shows the settings used for Scenario 2.

Table 7: Scenario 2 Inputs – Only Intensity of Hostilities Reduced

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	0	0	0
1	2	1	0	0	0
2	1	1	0	0	0
3	1	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0

Scenario 3

Scenario 3 tests the situation in which the US sends primary and secondary teachers to educate citizens of the DRC and train replacements. Following an initial surge in educators, these teachers will slowly leave until they all have returned to the US. They will, however, train locals to become teachers. In the initial year, 2,450 primary teachers are sent to the DRC. By year 1, 2,450 primary teachers and 240 secondary teachers have arrived in the DRC. By year 2, an additional 1,470 secondary teachers and 4,000 primary teachers arrive. Additionally, local teachers begin to replace the external teachers, which creates 3,000 jobs in the DRC. In year 3, an additional 1,770 secondary teachers arrive and 2,060 primary teachers arrive. An additional 3,000 teaching jobs are also created. The final 520 secondary teachers arrive in year 4, bringing the total teaching positions created by foreign aid to 8,510 primary teachers and 4000 secondary

teachers. Subsequently, in years 4 and 5, 1,000 teaching jobs are created each year, bringing the total jobs created to 8,000. This scenario assumes that while some teachers may begin to leave after a few years, their numbers will be replenished by new teachers arriving or by replacements being trained in-country. Table 8 shows the settings used for Scenario 3.

Table 8: Scenario 3 Inputs – Hostilities Constant, Increased Education Capability Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	1	0	0
1	3	2	4	.5	0
2	3	2	4	2.5	3
3	3	2	0	2	3
4	3	2	0	0	1
5	3	2	0	0	1

Scenario 4

Table 9: Scenario 4 Inputs – Hostility Constant, Increased Non-Educational Jobs Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	0	0	20
1	3	2	0	0	35
2	3	2	0	0	0
3	3	2	0	0	0
4	3	2	0	0	-5
5	3	2	0	0	-5

Scenario 4 looks at the situation where there is an increase in employment opportunities in the DRC beyond the educational arena. This scenario initially creates a large number of jobs opportunities, but after a three year period some of these jobs are no

longer available as projects are completed. In year 0, 20,000 jobs are added to the DRC by foreign aid actions. In year 1, an additional 35,000 jobs are added to the economy. In years 2 and 3, these 55,000 jobs continue with no net increases or decreases. However, in year 4, 5,000 jobs are no longer needed and are removed from the country. In year 5, an additional 5,000 jobs are removed, leaving a total of 45,000 induced jobs remaining in the country. Table 9 shows the settings used for Scenario 4.

Scenario 5

Scenario 5 combines aspects of Scenarios 3 and 4. Despite ongoing insurgent activity, primary and secondary teachers are sent from the US, as well as job opportunities being created. The input values for Jobs Created are the same as in Scenario 4. Additional primary and secondary teachers have the same inputs as scenario 3. Table 10 shows the settings used for Scenario 5.

Table 10: Scenario 5 Inputs – Hostilities Constant, Increased Education and Non-Education Jobs Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	1	0	20
1	3	2	4	.5	35
2	3	2	4	2.5	3
3	3	2	0	2	3
4	3	2	0	0	-4
5	3	2	0	0	-4

Scenario 6

Scenario 6 combines scenarios 2 and 3. Violence is reduced and primary and secondary teachers are sent into the DRC. The number of primary and secondary

teachers sent into the country and the effect they have on jobs is the same as in scenario 3. The decline in Magnitude Fatalities and Magnitude Fighting is the same as in scenario 2. Table 11 lists the inputs used for scenario 6.

Table 11: Scenario 6 Inputs – Hostilities Reduced, Increased Education Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	1	0	0
1	2	1	4	.5	0
2	1	1	4	2.5	3
3	1	0	0	2	3
4	0	0	0	0	1
5	0	0	0	0	1

Scenario 7

Scenario 7 combines elements of scenario 2 and scenario 4. The fighting and deaths are reduced over time, and additional jobs are created in the DRC. The decline in Magnitude Fatalities and Magnitude Fighting is the same as in scenario 2, and jobs are created according to the description of scenario 4. Table 12 lists the inputs used for scenario 7.

Table 12: Scenario 7 Inputs – Hostilities Reduced, Increased Non-Education Jobs Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	0	0	20
1	2	1	0	0	35
2	1	1	0	0	0
3	1	0	0	0	0
4	0	0	0	0	-5
5	0	0	0	0	-5

Scenario 8

Scenario 8 combines the first three scenarios. Combatant forces are reduced in number and effectiveness, which creates a more hospitable environment for international organizations and foreign enterprises to send educators and invest in the DRC economy, resulting in increases in job creation and teachers. The teachers and jobs are inserted and removed in the same time and quantities as Scenario 5. In addition, the number of insurgents and fatalities respond in the same manner as Scenario 2. Table 13 shows the settings used for Scenario 8.

Table 13: Scenario 8 Inputs – Hostilities Reduced, Increased Education and Non-Education Jobs Policy

Year of Simulation	Input Variable				
	Magnitude Fighting	Magnitude Fatalities	Additional Primary Teachers (K)	Additional Secondary Teachers (K)	Jobs Created (K)
0	3	2	1	0	20
1	2	1	4	.5	35
2	1	1	4	2.5	3
3	1	0	0	2	3
4	0	0	0	0	-4
5	0	0	0	0	-4

The methodology described in this chapter has detailed how operations research principles were used to construct the MMDRC. In an effort to ensure that the model performs as expected and is a useful representation of the real world, the verification and validation techniques described in Chapter II were performed on the MMDRC. Chapter IV contains the results of the V&V process and some of the implications those results have on the model.

IV. Establishing the Underlying Relations and Vetting

The methodology described in the previous chapter described how the system dynamics model representing migration was developed. Chapter III outlined how portions of the model were partially verified and validated. The regression analysis and statistical tests performed on the data to establish these relations is discussed in this chapter. The resulting equations and their relationship to the real world is also discussed. Following the discussion of the regression analysis, the subjective tests suggested by Shreckengost (Shreckengost) are then reviewed in relation to the model results.

Regressing the Data

The JMP 9.0 software package was used to perform linear and non-linear regression on the data to determine the relationships used in the model, and the impact they have on migration. A stepwise least squares regression was performed on each model output variable, using an F-test to enter and leave, with likely factors selected from the input and remaining model output variables as the independent variables. Variables to enter and remain in the model were required to pass the F-test at the $\alpha = 0.05$ level. The hypotheses for the F-test are:

For theses hypotheses, the number of observations is greater than *k*. Being unable to accept the null hypothesis indicates that at least one of the regressors has a non-zero beta coefficient. Once a statistically significant model was identified, it remained to

verify that the variables passed a t-test at the $\alpha = 0.05$ level. The hypotheses for the t-test are:

For theses hypotheses, the number of observations is greater than *k*, and *K* is the # of independent variables in the equation. The t-test null hypothesis is that the variable coefficient equals 0. Failing to accept the null hypothesis of the t-test implies that one is unable to accept the coefficient is zero; that is, it is assumed to have a non-zero value. Additionally, the correlation matrix was examined to determine if high multi-collinearity existed between variables. If factors failed the t-test, or high multi-collinearity was found, a stepwise regression was performed with the variable removed and the process repeated. After significance of the individual variables was determined, an F-test was performed on each regression equation to ensure that the equation as a whole was significant at the 0.05 level. A table showing the variables, their abbreviations, and definitions can be found in Appendix A.

Regression Equations

This section contains the individual regression equations for variables listed in Table 2 and Appendix A, the standard deviation (std) of each independent variable's coefficient, and the results of the t-test for each independent variable and constant term. Additionally, the number of recorded data points, n, used for the regression is listed. Note that the number of data points available is small. This can make the values obtained from the regression inaccurate and unsuitable for real world use. However, for this

demonstration these equations are useful in conveying relationships of the factors, as well as the complexity of modeling a single aspect of state failure.

Net Migration Rate (migrants per thousand)

NM =	1012.2	-	30.24*U	-	7.187*MFa
Std	(391.1)		(11.98)		(3.21)
Prob >|t|	(0.0206)		(0.0234)		(0.0407)

n = 18 Adj. R^2 = .656 Std dev = 13 Prob>F = 0.0001

This equation shows the relationship between the Net Migration Rate and its effectors, Unemployment and Magnitude Fatalities. For each percent increase in Unemployment, the number of people coming into the DRC each year decreases by 30.24 per thousand. Additionally, for each categorical increase in Magnitude Fatalities, the flow of people into the DRC each year decreases by 7.2 per thousand. These relationships are reasonable. This equation is valid for Unemployment values of $32.2 \leq U \leq 33.4$ and Magnitude Fatalities values of MFa = 0, 1, 2, 3, 4.

Education Index (unitless)

E =	0.339	-	0.0122*SSpT	+	0.000807*PT
Std	(0.0396)		(0.00246)		(0.0000767)
Prob >|t|	(<.0001)		(0.0002)		(<.0001)

n = 18 Adj. R^2 = .891 Std dev = 0.0126 Prob>F = <.0001

The regression equation for the Education Index suggests that increase in the number of primary and secondary teachers in the DRC will improve the education level. 12,400 additional primary teachers would affect a 0.01 increase in the Education Index, and an average of one additional student per teacher would reduce the Education Index by 0.0122. This is reasonable, as a greater number of teachers means greater opportunities to be taught and more individual attention for those students who attend.

This equation is valid for Secondary Students per Teacher values of $13.72 \leq SSpT \leq 20.26$, and Primary Teacher values of $114 \leq PT \leq 255.6$.

Change in Unemployment (percentage points per year)

CU =	0.531	-	1.68*E
Std	(0.195)		(0.698)
Prob >|t|	(0.0159)		(0.0295)

n = 17 Adj. R^2 = .23 Std dev = 0.103 Prob>F = 0.0295

This equation shows that for each 0.01 increase in the Education Index of the DRC, the unemployment rate decreases by 0.0168% a year. This is reasonable, as a more educated population produces more innovation and entrepreneurialism, which creates more jobs. It is noted that the equation is valid for Education Index values of $0.1977 \leq E \leq 0.3436$.

Gross National Income (millions of 2010 US dollars)

GNI =	-281638	+	288.5*LF	+	5542.6*PW
Std	(31119)		(81.62)		(608.4)
Prob >|t|	(<.0001)		(0.003)		(<.0001)

n = 18 Adj. R^2 = .902 Std dev = 779.3 Prob>F = <.0001

The GNI equation suggests that for each percentage increase of the population over 15 (the UN designated age to enter the workforce) the GNI increases by 5.54 billion 2010 US dollars. This is reasonable since this means there are proportionally more people available to work and produce income. Additionally, it is reasonable for the GNI to increase due to a rise in the Labor Force, as these are the people employed in the country, and as the number of people working increases, wealth should increase as well. The ratio of this increase is a 288.5 dollar increase in the GNI for every additional

worker. This equation is valid for 15+ Population values of $51.88 \leq PW \leq 53.33$ and Labor Force values of $14.05 \leq LF \leq 22.72$.

Birth Rate (births per thousand)

BR =	62.54	-	0.374*P	+	0.409*MFi
Std	(0.902)		(0.018)		(0.113)
Prob >|t|	(<.0001)		(<.0001)		(0.0023)

n = 19 Adj. R^2 = .96 Std dev = 0.581 Prob>F = <.0001

This equation suggests that for every million increase in the population, the birth rate decreases by 0.374 births per thousand per year. This is expected of the birth rate, as competition for resources and food can limit population growth. The relationship between the number of insurgents fighting and birth rate is counter-intuitive. It shows that for every categorical increase in the number of rebel combatants fighting there is a 0.409 increase in the number of births per thousand per year. In the case of the DRC, the positive relationship could be due to the large number of rapes committed by armed forces in the DRC. However, it is noted that Magnitude Fighting is a categorical variable and may produce inaccurate results when used in a regression model. Further investigation into this relationship is recommended for future analysis. This equation is valid for Population values of $37.94 \leq P \leq 64.21$, and Magnitude Fighting values of MFi = 0, 1, 2, 3, 4.

Death Rate (deaths per thousand)

DR =	46.84	-	0.0524*P	-	0.584*LE
Std	(2.089)		(0.014)		(0.048)
Prob >|t|	(<.0001)		(0.0018)		(<.0001)

n = 19 Adj. R^2 = .952 Std dev = 0.364 Prob>F = <.0001

The regression equation for death rate shows that for each million person increase in the population, the death rate decreases by 0.052 deaths per thousand per year. Additionally, each year of increased life expectancy results in a death rate decreased by 0.584 deaths per thousand per year. When people in the DRC live longer, there are less people dying, which is the expected result, although it is difficult to determine which factor is the cause and which is the effect. However, as aid policies would focus on increasing life expectancy, change in life expectancy will be considered the cause. This equation is valid for Population values of $37.94 \leq P \leq 64.21$,and Life Expectancy values of $44 \leq LE \leq 55$

Primary Pupils (thousands)

PP =	-4511	+	93.63*P	+	0.442*GNI
Std	(1237)		(30.1)		(0.0902)
Prob >|t|	(0.0024)		(0.0072)		(0.0002)

n = 18 Adj. $R^2 = .83$ Std dev = 728.9 Prob>F = <.0001

The regression shows that the number of primary pupils is a function of the size of the population and the GNI of the DRC. This equation suggests that for each increase of one million in population, there are 93,630 more primary pupils. Additionally, education can be costly in the DRC, so it is expected that as the GNI increases, improving financial situations would allow for more children to attend school. The regression equation estimates an additional 442 students for each million dollar increase of the GNI. This equation is valid for Population values of $37.94 \leq P \leq 64.21$, and Gross National Income values of $10,138 \leq GNI \leq 18,096$.

Change in Primary Teachers (thousands per year)

CPT =	-34.2	+	2.42*LF
Std	(8.84)		(0.5)
Prob >|t|	(0.0015)		(0.0002)

n = 17   Adj. R^2 = .585   Std dev = 4.76   Prob>F = 0.0002

This equation indicates that there is a linear relationship between the number of secondary teachers and the number of people employed in the DRC. For each million increase in the number of employed workers, there is a 2,420 increase in the number of primary teachers trained each year. This is a reasonable relationship as employed people could afford to send their children to school, which would create a higher demand for teachers. Additionally, teachers are part of the workforce, so if there are more workers in the country, it is reasonable that some of them are teachers. This equation is valid for Labor Force values of $14.05 \leq LF \leq 22.72$.

Secondary Pupils (thousands)

SP =	-4353	+	322.98*LF
Std	(120.5)		(6.1)
Prob >|t|	(<.0001)		(<.0001)

n = 10   Adj. R^2 = .997   Std dev = 35   Prob>F = <.0001

The number of secondary pupils in the DRC is dependent upon the size of the labor force. As the labor force increases, more people will seek additional education both in an attempt to become more employable, but also because families can afford to have a child stay in school. For each million increase in the number of employed workers, there is a 323,000 increase in the number of secondary students. This equation is valid for Labor Force values of $14.05 \leq LF \leq 22.72$.

Change in Secondary Teachers (thousands per year)

$$CST = -6.536 + 0.4856*PSpT$$

Std	(120.5)	(6.1)
Prob >|t|	(<.0001)	(<.0001)

n = 9   Adj. R^2 = .843   Std dev = 1.51   Prob>F = <.0001

The equation for the change in secondary teachers shows that as the average number of primary students per teacher increases by one, an additional 490 secondary teachers will be produced each year. This appears reasonable in that more students will be eligible for secondary education, and thus more teachers will be required and trained. Additionally, primary teachers could advance to teach secondary school, in an effort to acquire higher pay and prestige. This would cause a higher primary student to teacher ratio and increase the number of secondary teachers. This equation is valid for Primary Students per Teacher values of $25.74 \leq PSpT \leq 50.35$.

Combined Functions

In addition to the regressed equations mentioned, the model uses combined functions of the regressed and input variables to calculate additional output variables and regression factors. These equations are explained in the following section.

Population (millions)

P =

Since population is a stock variable, its value is based upon the flow of people into and out of the DRC throughout the entire simulation. The population of the current simulation year is calculated by adding the net migration rate to the birth rate and subtracting the death rate. Since this quantity is measured in births per million per year, it is multiplied by the current population to calculate millions of births per year.

Integrating this quantity over the simulation time yields the change in population from the initial value, and adding the initial population value give the value for the next year's population.

Unemployment (percentage, 0 – 100)

$$U = \qquad\qquad \text{——}$$

Unemployment is another stock variable in the model, and as such, the change in unemployment from year to year is modeled. The effect on unemployment by the policies of the current simulation year is found by first dividing the jobs created by foreign policies by the current population. This interim result has the same units as Change in Unemployment. This quantity is subtracted from the change in unemployment value and integrated over the simulation time to find the net change in unemployment. Adding this number to the initial unemployment rate will result in the unemployment rate of the next simulation year. This makes the conservative assumption that job growth is *only* associated with the changes effected by the policy scenario being tested.

Labor Force (millions)

$$LW = PW /100 * P * (100-U)/100$$

To calculate the labor force, the population is multiplied by the percentage of the population age 15+ and the result is multiplied by the employment rate of those 15+. Again, 15 is the international age of entering the workforce according to the World Bank (The World Bank, 2010).

GNI per Capita (2010 US dollars per capita)

$$GpC = GNI / P$$

The GNI per Capita is calculated by dividing the GNI, (Purchasing Power Parity, 2010 US dollars) by the population.

Primary Students per Teacher (unitless)

$$PSpT = PP / PT$$

The primary students per teacher ratio is calculated by dividing the number of primary students by the number of primary teachers.

Primary Teachers (thousands)

PT =

The number of primary teachers is a stock variable in the model and is a function of the integral of the change in primary teacher and additional primary teacher rates. The number of primary teachers is calculated by first integrating the sum of the change in primary teachers and additional primary teachers over the simulation time. This result is added to the initial number of primary teachers to give the total primary teachers in the country.

Secondary Students per Teacher (unitless)

$$SSpT = SP / ST$$

The secondary students per teacher ratio is calculated by dividing the number of secondary students by the number of secondary teachers.

Secondary Teachers (thousands)

ST =

The number of secondary teachers is a function of the integral of the change in secondary teacher and additional secondary teacher rates. The number of secondary teachers is calculated by first integrating the sum of the change in secondary teachers and

additional secondary teachers over the simulation time. This result is added to the initial number of secondary teachers to give the total secondary teachers in the country.

Subjective Tests of the Model

Given the equations driving the model, the model in its entirety was examined for robustness. The subjective tests proposed by Shreckengost and detailed in Chapter II are used to validate the model.

1) Model Parameter Tests – The parameters of the model are all derived from real world data and have reasonable results when fitted to actual data.

2) Boundary Adequacy Test – The model was built to model the net migration into the DRC in order to test the specified scenarios. While certainly other factors interact in the complex problem, this is the purpose for which it is being used.

3) Extreme Conditions Test – The extreme values of the input parameters can be handled by the model. However, running the model for decades can result in impractical values. Analysis of some of the regression equations indicate that certain extreme values could render implausible results, however, during the simulation of the scenarios these extreme values were never approached.

4) Behavior Replication Test – As shown in the section discussing the relations, the model tends to react in the same direction as one would expect in the real world. Several factors, however, do suggest further analysis is warranted as more data becomes available.

5) Anomalous Behavior Test – No unexpected anomalies were observed in the model. However, no anomaly was injected into the analysis to gauge its potential effect.

6) Behavior Sensitivity Test – Due to the nature of the real system, sensitivity analysis could not be performed on the real system. Changes in the model appear to behave consistent with predictions of how the real system would change. It should be noted, however, that while significant, some relations' standard deviations were large.

7) Behavior Prediction Test – As there are no existing systems representing migration in the DRC available, this test was unable to be performed.

8) Family Member Test – The model framework is constructed in such a way that it could be applied to other countries. However, coefficients of the regression

equations are likely unique to the DRC. Country data should be fitted and analyzed to determine adjustments to parameter values.

9) Behavioral Boundary Test – The boundaries of the model are sufficient to deal with foreseeable excursions in the DRC. Expanding the use of the model to a region differing from that of the DRC may give inaccurate results due to the social, political, and economical differences. As the test policies are focused on the DRC, the DRC was an acceptable boundary.

The conclusions of these tests indicate that the results of the model are reasonable for the proposed purpose and can be useful in gaining insight into the effects US policies have on net migration. It is noted that results acquired from extended time horizons may be inaccurate. This is due to variability which is not captured in the model, and the inaccuracy of regressions as they are extended beyond the set from which they were formed.

This chapter has suggested that the MMDRC is a reasonable representation of net migration in the DRC for examining near future support policies. Chapter V investigates the impacts certain policy actions could have on the net migration situation in the DRC. A design of experiments was created and executed using 4 inputs to test the statistical significance of policy variations. Six hypothetical scenarios were then simulated using MMDRC and their results are analyzed.

V. Analysis of Demonstration Scenarios

Using the methodology described in Chapter III, a system dynamics model was developed to investigate the possibility of evaluating the effects of notional policies on net migration in the Democratic Republic of Congo. Regression analysis was performed to fit underlying relationships relating to migration. In addition, a Design of Experiments and test scenarios were described. Chapter IV reviewed the regression equations and the model in general to gain confidence that the output produced by the MMDRC was accurate and useful. This chapter analyzes the results obtained from executing a DOE created to test the effects the proposed policies had on net migration.

Design of Experiments Results

The DOE described in Chapter III was implemented to determine the effects of policy driven factors. A mixed level design was used in order to test the full range of categorical input values as well as possible values for the continuous variables. A table of the runs executed in the design is contained in Appendix C. Upon completing the 25 runs required for the design, the main effects were analyzed to determine their significance to net migration in the initial year, 2011, and the subsequent five years of simulation time.

The Net Migration Rate was the output of interest for this simulation. The values of the Net Migration Rate obtained from the model runs are contained in the following tables. Table 14 shows the level of net migration obtained from the execution of the DOE. Table 15 shows a list of the significant inputs to the migration rate for each year studied.

Table 14: Results of Net Migration Rate (People per Thousand per Year) for Test Runs

Run #	2011	2012	2013	2014	2015	2016
1	-17.92	-6.6	-1.3	5.05	12.39	20.7
2	3.64	-6.7	-1.51	4.76	12.07	20.38
3	-25.11	-5.08	0.13	6.36	13.57	21.74
4	-10.73	-6.65	-1.41	4.89	12.2	20.49
5	-3.55	-5.15	-0.01	6.19	13.4	21.59
6	-3.55	-6.71	-1.53	4.72	12	20.27
7	-10.73	-5.17	-0.07	6.09	13.24	21.38
8	-25.11	-6.62	-1.36	4.94	12.24	20.49
9	3.64	-5.28	-0.3	5.76	12.85	20.95
10	-3.55	-6.73	-1.59	4.64	11.89	20.14
11	-17.92	-6.63	-1.36	4.96	12.28	20.56
12	3.64	-6.78	-1.7	4.47	11.69	19.92
13	-3.55	-5.18	-0.08	6.08	13.26	21.43
14	-25.11	-6.52	-1.1	5.34	12.77	21.14
15	-10.73	-5.06	0.2	6.49	13.79	22.04
16	-25.11	-4.96	0.41	6.79	14.14	22.43
17	-10.73	-6.68	-1.48	4.78	12.07	20.33
18	-17.92	-5.02	0.29	6.62	13.94	22.21
19	3.64	-5.21	-0.14	6	13.18	21.35
20	-17.92	-5.13	0.02	6.21	13.4	21.55
21	3.64	-5.98	-0.9	5.27	12.47	20.68
22	-3.55	-5.94	-0.79	5.42	12.66	20.88
23	-10.73	-5.89	-0.68	5.58	12.84	21.08
24	-17.92	-5.84	-0.57	5.73	13.02	21.28
25	-25.11	-5.79	-0.46	5.88	13.21	21.48

A comparison of Table 14 with the inputs of each run shows that the fluctuations in the net migration in 2011 are due entirely to the value of Magnitude Fatalities. This is because the 2011 values are calculated at the simulation start time before the flows in the system are turned on. Magnitude Fatalities is the only input that does not go through a stock or flow variable before affecting net migration. 2012 is the first simulation year when all input factors affect net migration. It is also important to note that the values for net migration all lie within the range of values seen in the historical data, indicating that these results are realistic.

Table 15: Significance of Input Variables on Net Migration Rate

Input Variable	Prob > F in 2011	Prob > F in 2012	Prob > F in 2013	Prob > F in 2014	Prob > F in 2015	Prob > F in 2016
Magnitude Fighting	1.0	<.0001	<.0001	<.0001	<.0001	<.0001
Magnitude Fatalities	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Jobs Created	1.0	<.0001	<.0001	<.0001	<.0001	<.0001
Additional Primary Teachers	1.0	<.0001	<.0001	<.0001	<.0001	<.0001
Additional Secondary Teachers	1.0	<.0001	<.0001	<.0001	<.0001	<.0001

The results shown in Table 15 indicate that all five input variables have significant effects on the Net Migration Rate in this model at the $\alpha = 0.01$ level. Additionally, a change in an input in the first year of simulation will continue to have a significant effect in future simulation years. Table 15 also shows that Magnitude Fatalities is the only input that affects the initial level of Net Migration. This is due to the layout of the model and how the Vensim software calculates initial values. Increasing jobs and/or the number of teachers in the DRC is predicted to have a positive effect on the net migrants entering the DRC. Additionally, the model suggests that reducing the number of combatants and fatalities in the DRC will increase the net migration into the country. Creating jobs in the DRC appears to have the greatest effect on migration. This is true for all simulated years, with the exception of the initial year. Magnitude Fatalities has a large impact on the results of the simulation, but is surpassed as the second greatest effector in 2014 by Additional Primary Teachers. The variable with the next largest impact was Additional Secondary Teachers. The smallest impact came from the Magnitude Fighting, although it was still statistically significant. It should be recalled, however, that in this demonstration, data was limited and the modeling was restricted to a single facet of failing states. Once the input variables were shown to have a significant

impact on net migration, the test scenarios developed in Chapter III were simulated with the model to determine which notional policies might have the greatest impact on net migration flow.

Scenario Results

As described in Chapter III, eight hypothetical US policies were created and then simulated using the MMDRC. The figures on net migration in this model are simply that; net migration without a distinction of who entered or left the DRC or why. For the purpose of the demonstration analysis it is assumed that positive net migration (Immigration into the country) is desirable. Clearly, if this inflow were refugees fleeing a neighboring warring state it would not be desirable. However, positive net migration will be used for this demonstration. The results of the simulation with regards to net migration are detailed in this section. Table 16 shows the Net Migration Rate, in migrants per thousand per year, results for the first six years of the simulated scenarios.

The results listed in Table 16 show that scenario 8, which employs policies aimed at reducing violence, bolstering education, and creating jobs, has the largest favorable impact on net migration into the DRC. These results show that there is an additive effect among the three notional policies of reducing violence, increasing education, and creating jobs, quelling the violence has the greatest effect throughout every year of the simulation. Its effect is larger than the combined effect of creating jobs and sending teachers to the country. Sending primary and secondary teachers into the country initially has a very small impact, but its impact grows larger as time progresses and becomes the second most significant individual policy of net migration change. Job creation is the second largest factor in the first several years of the simulation, but by 2016 it begins to have less

of an impact on migration than the education policy. This is likely due to the diminishing impact of the creating a set number of jobs with an increasing population. This policy suggests that job creation has an immediate effect as people tend to migrate towards countries where work is available.

Table 16: Results of Net Migration Rate (Migrants per Thousand per Year) for Simulated Scenarios

Scenario	2011	2012	2013	2014	2015	2016
1 (Constant)	-10.73	-6.72	-1.59	4.62	11.85	20.07
2 (Violence)	-10.73	0.44	5.46	18.62	25.45	33.12
3 (Education)	-10.73	-6.68	-1.28	5.44	13.18	21.83
4 (Jobs)	-10.73	-5.56	0.31	6.45	13.5	21.43
5 (3 & 4 combined)	-10.73	-5.51	0.61	7.27	14.83	23.19
6 (2 & 3 combined)	-10.73	0.48	5.76	19.44	26.78	34.89
7 (2 & 4 combined)	-10.73	1.61	7.35	20.44	27.09	34.48
8 (1, 2, & 3 combined)	-10.73	1.65	7.65	21.26	28.42	36.25

Chapter V presented the results of a DOE used to measure the impact of input variables on the net migration rate into and out of the country. In addition, this chapter presented the results of eight scenarios in which notional aid policies could be used to affect the net migration rate. A word of caution must be presented here. The model of net migration demonstrates that modeling can assist in evaluating policies in failing states. However, it also helps to illustrate that the complex elements of nation building may not be successfully modeled in separation. By focusing only on net migration, and not capturing additional interactions, MMDRC has limited value beyond demonstrating

the potential value of a more complex DRC model. With a finer granularity of the elements of net migration, and interaction with economic, ethnic strife, internal migration, and so forth, compiled with sufficient data to support such a model, a more accurate and detailed analysis could be made. MMDRC does, however, demonstrate the possibility. Chapter VI will discuss the impact of this research and areas of interest for future research opportunities.

VI. Conclusion

This chapter contains a summary of the research presented in this study. Additionally, recommendations for future uses of this study are put forth along with areas where future research could prove useful to the problem area.

Research Summary

This thesis underscored the importance of bolstering weak and fragile states in order to prevent the societal calamities that accompany failed states. In an effort to gain insight into policies that could alleviate demographic tension in a country caused by net migration, the Migration Model of the Democratic Republic of Congo (MMDRC) model was developed. To develop the MMDRC, data concerning various aspects of the economic and educational attributes of the DRC were studied and regressed along with measurements of violent conflict in the country. Operations research principles were utilized to construct a dynamic, time-continuous model which could be used to analyze the effects foreign aid policies have on the net migration rate of the DRC. After the completion of the MMDRC, six scenarios were examined to determine the impact hypothetical foreign actions would have on the country.

Research Findings

This research suggested that system dynamics could be useful in modeling complex human interactions, specifically migration flow. Estimations of the impacts of future policies were able to be modeled to give insight into the future migration rate of the DRC.

Analysis of the MMDRC showed that policies which establish peace in the DRC by reducing the number of deaths in the country have the largest effect on net migration. This finding supports the theory that armed conflict in a region deters migration into the area. Additionally, the model indicated that job creation has a large impact in the first few forecasted years, but as time goes on, the number of teachers sent and trained becomes more significant. This finding is of interest to decision makers as objectives that require rapid increases in the net migration would be best reached by creating jobs instead of sending educators, whereas longer term objectives for migration increase may best be served by sending teachers into the country.

The MMDRC does have a number of limitations. While this pilot study does demonstrate the potential use of modeling to assess potential courses of action, it also highlights these limitations. Scarcity of reliable data focused this study into modeling a single aspect of failing states, net migration. The complexity of human interaction cannot be captured in a single key element. This strongly suggests that future work balance the granularity required, the levels of complexity incorporated, and the data availability required to build supporting tools for nation building. In addition, one must consider the question, or questions, to be addressed.

Areas of Future Research

While this study analyzed an aspect of the armed conflicts occurring in the DRC, further study of these in relation to refugees could prove beneficial. The armed conflict data used in the study was categorical and thus ill-suited for use in a dynamic model. If continuous data regarding the armed conflict becomes available, incorporating fitted regression equations of the data into the MMDRC could provide more insight into how

violent conflict affects migration, as well as interactions between conflict and the economy and education level of the DRC.

While it is worthwhile to have an understanding of what drives people away from the DRC, or any country, it is also important to know the destination of migrants in order to assess the future stability of the receiving nations. Research into where migrants from the DRC travel, as well as what draws migrants from other nations into the DRC could give insight into future nations, or areas, where instability could be a cause for concern.

It is recognized that migrants who cross international borders are not the only type of migrant of interest when studying nation instability. Internally displaced persons can be an additional stressor on nation stability. This is of particular concern in the DRC where there are numerous different ethnic groups in the country and a history of conflict between them. Research into the tribal interactions within the DRC and how they drive conflict and corruption could prove particularly helpful in gaining insight into internal migration and internally displaced persons and the impact they have on international refugees and migration.

Conclusions

The Democratic Republic of Congo is a country with a vast amount of economic potential; however, corrupt leadership and continual warfare has put the nation on the brink of collapse. Understanding the role migration plays in the stability of the nation is vital to building sound foreign policies to mitigate the problems occurring in the DRC. To understand the many relationships and factors that affect net migration, it is important to have accurate models to represent the complexities of the problem. The MMDRC uses system dynamics to model elements involved in predicting policy effects on the net

migration rate in the DRC. It was used to show that foreign policies involving quelling armed conflict, job creation, and boosting education in the country had statistically significant impacts on migration in future years. Critical to utilizing such modeling, however, will be the development of accurate longitudinal data on failed and failing states. The exact conditions that exist in failing states often make accurate data difficult to obtain to support modeling. Future research into the armed conflicts and internal migration of the DRC could provide even further insight into how the US could act to stabilize the DRC. It is the sincere hope of this study that the model presented in this thesis will give insight into the complexities involved with modeling failing states and highlight the need for improved tools to aid decision makers in drafting policies that will speed the recovery and stabilization of failing states.

Appendix A: Model Variables and Sources

Factor	Symbol	Description	Source
Population (Total)	P	Millions of people in the Democratic Republic of Congo	WB
Net Migration	NM	The number of people per million per year who enter (positive value) and leave (negative value) the DRC	WB
Unemployment	U	The percentage of the population 15+ who are unemployed in the DRC	WB
Change in Unemployment	CU	The change in the unemployment percentage in the DRC in a year	WB
Labor Force	LF	The number of people (in thousands), age 15+, who are employed in the DRC	WB
GNI per Capita	GpC	The Gross National Income (Purchasing Power Parity, or PPP) per capita in the DRC, measured in 2010 US$	WB
Education Index	E	0 to 1 value used by the UN to represent educational opportunity and expectations in the DRC	UNDP
GNI	GNI	The Gross National Income (PPP) of the DRC measured in millions of 2010 US$	WB
Birth Rate	BR	Number of live births per thousand per year in the DRC	WB
Death Rate	DR	Number of deaths per thousand per year in the DRC	WB
Primary Students per Teacher	PSpT	The number of primary students per primary teacher in the DRC	WB
Primary Pupils	PP	Number of primary students in the DRC measured in thousands	WB
Primary Teachers	PT	Number of primary teachers in the DRC measured in thousands	WB
Change in Primary Teachers	CPT	The increase or decrease in the number of primary teachers in the DRC, in thousands per year	WB
Secondary Students per Teacher	SSpT	The number of secondary students per secondary teacher in the DRC	WB
Secondary Pupils	SP	Number of secondary students in the DRC measured in thousands	WB
Secondary Teachers	ST	Number of secondary teachers in the DRC measured in thousands	WB
Change in Secondary Teachers	CST	The increase or decrease in the number of secondary teachers in the DRC, in thousands per year	WB
Refugees Out	RO	The number of people from the DRC, in thousands, who are refugees or in refugee-like situations living outside the DRC	UNHCR

WB: The World Bank (http://data.worldbank.org/indicator)
UNDP: The United Nations Development Program (http://hdrstats.undp.org/en/tables/default.html)
UNHCR: The United Nations High Commissioner for Refugees
(http://apps.who.int/globalatlas/DataQuery/default.asp)
PITF: Political Instability Task Force (http://www.systemicpeace.org/inscr/inscr.htm)
USCB: United States Census Bureau International Database
(http://www.census.gov/ipc/www/idb/country.php)

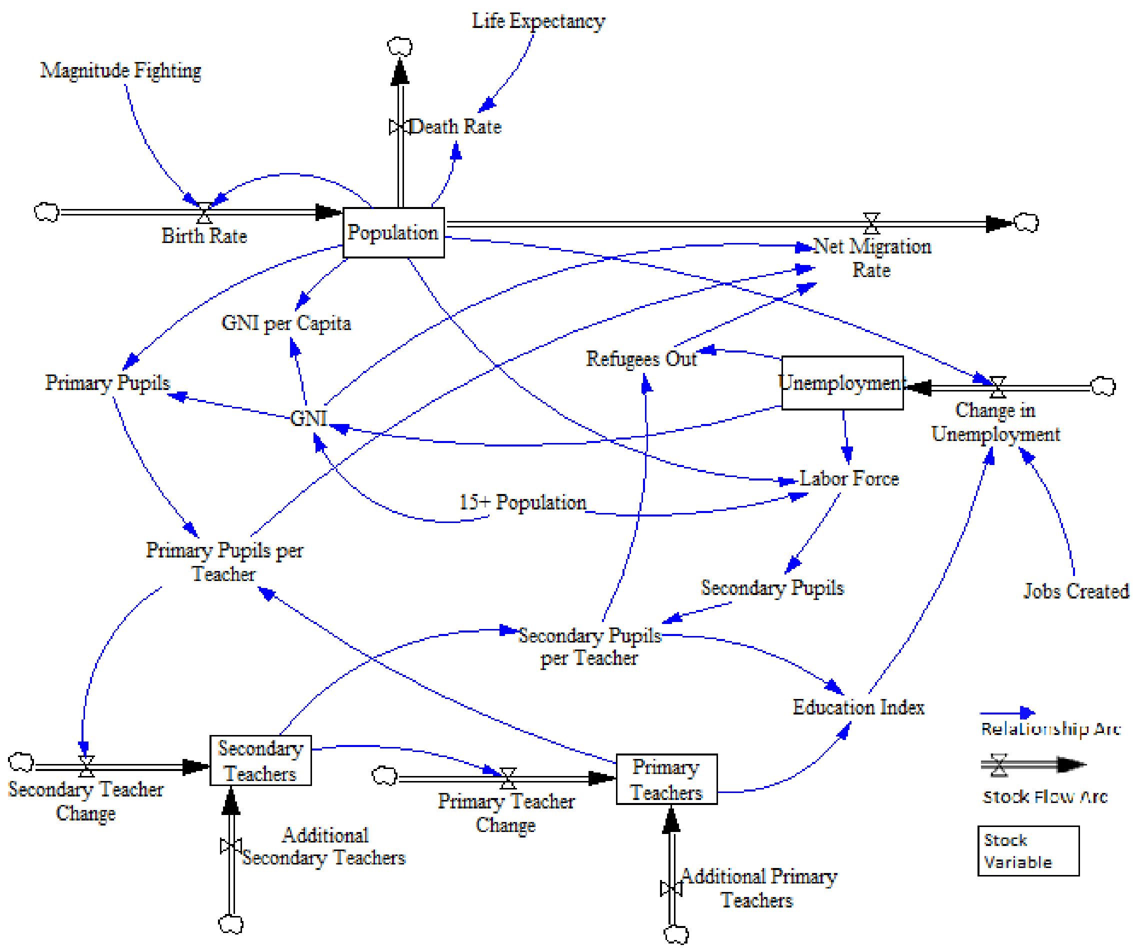
Factor	Symbol	Description	Source
15+ Population	PW	The percentage of people over the age of 15 in the DRC	WB*
Life Expectancy	LE	The life expectancy at birth for the DRC	USCB*
Magnitude Fighting	MFi	A dummy variable, 0-4, that represents the number of combatants or activists participating in an uprising	PITF**
Magnitude Fatalities	MFa	A dummy variable, 0-4, that represents the number of deaths caused by a conflict	PITF**
Magnitude Area	MA	A dummy variable, 0-4, that represents the land area size where the conflict is occurring	PITF**
Jobs Created	JC	The number of jobs (thousands) created in the DRC by US policies	N/A***
Additional Primary Teachers	APT	The number of primary teachers (thousands) created in the DRC by US policies	N/A***
Additional Secondary Teachers	AST	The number of secondary teachers (thousands) created in the DRC by US policies	N/A***

* These variables were used in the model regression and are not altered in the scenarios

** These variables were used in the model regression and are altered in the scenarios

*** These variables were not used in the model regression and are altered in the scenarios

Appendix B: Diagram of the Migration Model of the Democratic Republic of Congo (MMDRC)



Appendix C: Design of Experiments Run Parameters

Run Number	Magnitude Fighting	Magnitude Fatalities	Jobs Created	Additional Primary Teachers	Additional Secondary Teachers
1	1	3	0	5.15	0
2	0	0	0	5.15	3.09
3	4	4	70	0	0
4	2	2	0	5.15	0
5	0	1	70	5.15	0
6	4	1	0	5.15	0
7	0	2	70	0	0
8	1	4	0	0	0
9	2	0	70	0	0
10	2	1	0	0	3.09
11	0	3	0	0	3.09
12	4	0	0	0	3.09
13	1	1	70	0	3.09
14	3	4	0	5.15	3.09
15	1	2	70	5.15	3.09
16	2	4	70	5.15	3.09
17	3	2	0	0	3.09
18	4	3	70	5.15	3.09
19	3	0	70	5.15	0
20	3	3	70	0	0
21	0	0	35	2.575	1.545
22	0	1	35	2.575	1.545
23	0	2	35	2.575	1.545
24	0	3	35	2.575	1.545
25	0	4	35	2.575	1.545

Appendix D: Blue Dart

Why Are You Leaving?

Imagine you live in a country where armed insurgent and government troops ravage and pillage local villages, one in three people are out of work, nearly half of all women are unable to read, and the average person lives on less than two dollars a day. Now ask yourself, "What would take to get me to stay here instead of running for the nearest national border?" While you may never be faced with this situation in your own lifetime, it is a stark reality for the citizens of one of Africa's most populated nations, the Democratic Republic of Congo (DRC).

International migration is a source of tension between nations, as well as the citizens of the host country. This becomes obvious by a quick examination of recent migration issues throughout the world. As migrants move into a host country, they can place added stress on host country resources, as well as disrupting the political status quo in the region where they settle. In 1996, the large migration into the DRC of Hutu tribesmen fleeing retribution for the Rwandan genocide played a large part in the toppling of the regime which had controlled the DRC for the past 30 years. While most of the Rwandan refugees were repatriated after a couple of years, eastern DRC continues to suffer from chronic human rights violations, poverty, and instability.

It is important for US foreign policy decision makers to understand what causes migration in a country. This knowledge could then be used to inform decisions that will affect migration and nation stability. While it is recognized that each situation is different, there are common themes in the reasons people give for leaving their homes. The Migration Model of the Democratic Republic of Congo (MMDRC), developed by

Capt. Michael Thompson at the Air Force Institute of Technology, examines three of these common themes: violence, employment, and education.

Findings of the MMDRC indicate that decreasing the levels of violence in the DRC would have the greatest impact on creating favorable net migration in the DRC, with education and jobs having a lesser, though still positive effect. However, the model highlights the need for reliable data concerning failing states. This lack of accurate, longitudinal data is an inhibitor to any study on courses of action to promote nation stability in the DRC, or other failing states. Additionally, Capt Thompson's research shows that decisions should not be based solely on the number of migrants entering and leaving a country. The attributes of the individual migrants are important to know. Are the people coming in to a country trained professionals making a voluntary choice to move, or are they poverty stricken villagers who were forced out of their previous home at gun point? Unfortunately this information is unavailable.

Migration is a complex issue and is a part of the even more complex problem of nation stability. These complexities make decisions solely targeted to a single element of state failure inappropriate, as important relationships will be removed. State failure is a problem that needs to be examined in its entirety; in order to accomplish that additional research needs to be conducted and data gathered to accurately represent the nations and regions involved.

- *Captain Michael Thompson is a graduate student at the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio.*

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REPORT DOCUMENTATION PAGE

Form Approved
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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
24-03-2011	**Graduate Research Project**	Aug 2011 – Mar 2011

4. TITLE AND SUBTITLE

MIGRATION ISSUES IN THE DEMOCRATIC REPUBLIC OF CONGO

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Thompson, Michael J., Captain, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Street, Building 642
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT-OR-MS-ENS-11-24

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Mr. August G. Jannarone USSOCOM HQ
7701 Tampa Point Blvd
Bldg. 501A, Rm. 121, J51
MacDill AFB, FL 33621-5323

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution A : APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Since the end of the Cold War, the number of weak and failing states has increased significantly. The United States (US) military has been deployed in multiple nation states in an effort to prevent these weak states from collapsing into chaos. This thesis explores one of the driving factors of state collapse, net migration, to gauge how US foreign policy might be employed to reduce the flow of people out of a country. To demonstrate the foreign policies and their effects, a pilot model was constructed using a system dynamics methodology. The Democratic Republic of Congo (DRC) was selected as a preliminary study for the model implementation.

This thesis examines three notional policies which could be implemented in the DRC: a reduction in the armed conflict occurring in the eastern provinces of the DRC, increasing the number of primary and secondary teachers in the DRC, and increasing the number of employment opportunities in the DRC. Interactions between different factors and drivers of migration are analyzed and included in the system dynamics model. Several scenarios are tested using this model, and the results of these scenarios, as well as their implications for future policies, are detailed.

15. SUBJECT TERMS

Migration, Democratic Republic of Congo, System Dynamics, Failing State, Nation Stability

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Dr. Richard F. Deckro (ENS)
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
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